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Simulations of formation and development of river deltas in the environments of Earth and Titan

Abstract

The *Cassini-Huygens* mission to the Saturn system has revolutionized our knowledge of Titan, the largest icy moon of the planet. One of the most important discoveries is the finding of hydrocarbon lakes and river valleys on the surface of Titan. Hydrocarbon rivers are capable of transporting loose material in the same way as terrestrial rivers transport grains of rock. Sediments are deposited during transport, in particular in areas where a river enters a standing body of liquid. In these places river deltas are formed. The deltas have various dimensions, inclination and shapes, depending on the type of terrain, discharge, shaping processes and the size of grains.

Using a numerical model based on the finite elements method I simulated the processes of sedimentation occurring in terrestrial and Titanian environment. Various possible densities of transported sediments were considered, and the effect of different discharges and the dominant grain sizes was examined. The advantage of this model over the commonly used Reduced Complexity Models is the use of the universal Navier-Stokes equations to describe the flow and the adequate equations describing sediment transport. Despite the obvious advantages, models of the formation and development of deltas based on the equations of hydrodynamics are relatively few, and they are rarely used to simulate processes in an environment other than terrestrial.

The model described here represents a small river delta, but has a high spatial resolution, allowing to capture processes with a small spatial scale. For the first time this method was applied to formation of deltas from the solid material with a density of basalt, which is important for rivers flowing in the areas of young basaltic volcanism on Earth. Also no one before had tried to apply this kind of calculation for Titan.

This work is an extension of previous publications, the first of which was published in the *Planetary and Space Science* journal in 2015 (Witek & Czechowski, 2015), the second was sent for publication in the same journal (Witek & Czechowski, 2015b), while the third and fourth have been submitted for publication in the *Geological Quarterly* (Witek et al., 2016 Misiura et al., 2016). These works describe the differences in the processes

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of formation and development of river deltas in the environments of Earth and Titan (for a few values of discharge), resulting from the different values of the gravitational acceleration, the density of liquids and solids, and viscosity of liquid on these two celestial bodies.

The model allows to obtain realistic results, which can be explained by analyzing the local forces. The results lead to the following conclusions: (1) the development of the delta for the basalt grains qualitatively occurs as for the quartz grains; (2) the flow velocity field for different liquids on Titan practically does not depend on the type of liquid; (3) the development of the delta on Titan strongly depends on the density of sediments, for water ice grains the transport rate is greater than for the quartz material on the Earth; (4) some depositional landforms on Titan, morphologically corresponding to forms on Earth, can be built of sediment grains of a larger diameter than the terrestrial landforms; (5) three different types of the general morphology of the deposits were distinguished: the dominance of erosion at the mouth of the river, the formation of lobate deltas and the formation of fan deltas. In the case of Titan the area of the parameter space corresponding to lobate deltas is narrower than that on the Earth.

Research on Titan's fluvial geomorphology is necessary for the proper interpretation of the landforms observed in radar and infrared images of the surface. My work deepens the understanding of the processes shaping the surface of this geologically active body.